BALL TRAJECTORY MEASURING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an apparatus for measuring the trajectory of a flying ball.

2. Description of the Related Art

A golf ball flies by hitting through a golf club. If the trajectory of the flying golf ball can be measured, the evaluation of the performance of the golf ball, the evaluation of the performance of the golf club and the diagnosis of the swing form of a golf player are carried out.

Japanese Laid-Open Patent Publication No. 6-323852 has disclosed a measuring apparatus using a CCD camera having a shutter function. In this apparatus, image data photographed by the CCD camera are fetched into a calculating portion and a change between image frames is written to a multilayer memory by an image processing. The trajectory of a golf ball is measured from a multilayered image thus obtained. In the measuring apparatus, the trajectory of the golf ball can be observed but time series data on the position coordinates of the golf ball cannot be measured.

Japanese Laid-Open Patent Publication No. 2001-145718 has disclosed an apparatus for measuring the trajectory of a golf ball based on image data obtained by a CCD camera provided behind a launch point and image data obtained by a CCD camera provided on the side of the trajectory). In this apparatus, a large number of CCD cameras are required to be provided on the side. In order to measure the trajectory with high precision by this apparatus, furthermore, a distance between the CCD camera provided on the side and the golf ball is to be sufficiently increased. In general golf courses and examination sites of golf equipment manufacturers, a distance in a hitting direction is long and a side space is small. The installation of the apparatus has many restrictions.

Furthermore, there has also been proposed an apparatus for photographing a golf ball from both sides by means of two CCD cameras provided on the right and left sides of a trajectory. In this apparatus, the trajectory of the golf ball is measured based on a pair of image data by a triangulation method. In order to measure the trajectory with high precision by this apparatus, it is necessary to set a distance between the left and right CCD cameras to be sufficiently great. In order to install the apparatus, it is necessary to take a very large side space. The installation of the apparatus has many restrictions.

There can also be proposed means for measuring a trajectory by an apparatus comprising a CCD camera provided behind a launch point and a CCD camera provided before a drop point. In the measurement using this apparatus, a very large side space is not required. In order to photograph the trajectory within a wide range by this apparatus, a wide angle CCD camera is required. In the wide angle CCD camera, precision in the measurement is insufficient. In the case in which the position coordinates of a golf ball are calculated immediately after a launch and immediately before a drop (in other words, a golf ball in a low position), the precision is particularly insufficient.

It is an object of the present invention to provide a ball trajectory measuring apparatus which can easily be installed and can measure time series data on the position coordinates of a flying ball with high precision.

SUMMARY OF THE INVENTION

The present invention provides a ball trajectory measuring apparatus comprising a first camera for photographing a flying ball from a back part, a second camera having an angle of view related to that of the first camera and serving to photograph the ball from the back part later than the first camera, a third camera for photographing the ball from a front part, a control portion for controlling photographing timings

of the first, second and third cameras, and a calculating portion for calculating position coordinates of the ball based on image data obtained by the first, second and third cameras, and position coordinates, directions of optical axes and angles of view of the respective cameras.

In the measuring apparatus, the camera is not provided on a side. Accordingly, a very large side space is not required. In the measuring apparatus, the photographing is carried out from the back part by means of the first camera and the second camera and is carried out from the front part by means of the third camera. The position coordinates of the ball are calculated by a triangulation method based on image data obtained by the photographing from the back part and image data obtained by the photographing from the front part. The photographing to be carried out from the back part is relayed from the first camera to the second camera. The angle of view of the second camera is related to that of the first camera. Therefore, the ball can be photographed within a wide range of the trajectory through the relay.

It is preferable that the first camera should be positioned behind a ball launch point, the second camera should be positioned between the launch point and a drop point, and the third camera should be positioned before the drop point. Since the second camera is positioned between the launch point and the drop point, an angle formed by an optical axis in a horizontal direction can be set to be great. The angle of elevation of the golf ball measured immediately before the drop by means of the second camera is great. The measuring apparatus has high precision in the measurement of the ball immediately before the drop.

It is preferable that the angle of view of the first camera should partially overlap with that of the second camera. The angle of view of the second camera is related to that of the first camera based on ball images which are simultaneously photographed by the first camera and the second camera. This apparatus is excellent in precision in the measurement.

Another invention provides a ball trajectory measuring apparatus comprising a first camera for photographing a flying ball from a front part, a second camera having an angle of view related to that of the first camera and serving to photograph the ball from the front part earlier than the first camera, a third camera for photographing the ball from a back part, a control portion for controlling photographing timings of the first, second and third cameras, and a calculating portion for calculating position coordinates of the ball based on image data obtained by the first, second and third cameras, and position coordinates, directions of optical axes and angles of view of the respective cameras.

In the measuring apparatus, the camera is not provided on a side. Accordingly, a very large side space is not required. In the measuring apparatus, the photographing is carried out from the back part by means of the third camera and is carried out from the front part by means of the first camera and the second camera. The position coordinates of the ball are calculated by a triangulation method based on image data obtained by the photographing from the back part and image data obtained by the photographing from the front part. The photographing to be carried out from the front part is relayed from the second camera to the first camera. The angle of view of the second camera is related to that of the first camera. Therefore, the ball can be photographed within a wide range of the trajectory through the relay.

It is preferable that the first camera should be positioned before a ball drop point, the second camera should be positioned between a launch point and the drop point, and the third camera should be positioned behind the launch point. Since the second camera is positioned between the launch point and the drop point, an angle formed by an optical axis thereof in a horizontal direction can be set to be great. The angle of elevation of the golf ball measured immediately after the launch by means of the second camera is great. The measuring apparatus has high precision in the measurement of the ball

immediately after the launch.

It is preferable that the angle of view of the first camera should partially overlap with that of the second camera. The angle of view of the second camera is related to that of the first camera based on ball images which are simultaneously photographed by the first camera and the second camera. This apparatus is excellent in precision in the measurement.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a view showing the schematic structure of a ball trajectory measuring apparatus according to an embodiment of the present invention,

Fig. 2 is a side view showing a state in which the trajectory of a golf ball is measured by the apparatus in Fig. 1,

Fig. 3 is a side view showing another measuring method using the apparatus in Fig. 1, and

Fig. 4 is a side view showing a state in which the trajectory of the golf ball is measured by a ball trajectory measuring apparatus according to another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the present invention will be described below in detail with reference to the drawings.

An apparatus shown in Fig. 1 comprises a first camera 1, a second camera 2, a third camera 3, a control portion 4 and a calculating portion 5. The first camera 1, the second camera 2 and the third camera 3 are CCD cameras having a shutter function. The control portion 4 and the calculating portion 5 include a computer and a peripheral apparatus. The control portion 4 and the calculating portion 5 may be constituted by the same computer. A ball trajectory measuring apparatus may comprise a printing portion, a display portion and the like which are not shown.

The control portion 4 detects a trigger signal generated

by hitting a golf ball and then transmits a signal to the calculating portion 5 in order to start to record image data. Moreover, the control portion 4 transmits a synchronizing signal toward the first camera 1, the second camera 2 and the third camera 3. A plurality of synchronized images is obtained by the first camera 1, the second camera 2 and the third camera 3 which receive the synchronizing signal.

The calculating portion 5 records, for each frame, image data obtained by the first camera 1, the second camera 2 and the third camera 3. For the recording, a time plus VTR, a digital disk recorder, an animation board or the like can be used. The data thus obtained are used for an image processing. In the image processing, a difference peak hold calculation is carried out in order of frames for the image data. More specifically, only a pixel memory for a changed peak in the pixel of each frame memory is held and other memories are erased. The image of a golf ball is whiter than a background and is obtained as the whitest portion in a decision of shading. Consequently, the background is erased by the image processing so that it is possible to obtain data in which only the image of the golf ball remains.

Fig. 2 is a typical side view showing a state in which the trajectory of the golf ball is measured by the apparatus in Fig. 1. Fig. 2 shows a golf ball G and a trajectory T of the golf ball G. The golf ball G flies from left to right in Fig. 2. In Fig. 2, Ps denotes a launch point and Pe denotes a drop point. As shown in Fig. 2, there can be supposed two-dimensional position coordinates in which the position of the first camera 1 is set to be an origin, a straight line connecting the first camera 1 and the second camera 2 is set to be an X axis and a direction of a height is set to be a Z axis.

The first camera 1 and the second camera 2 are provided behind the launch point Ps. The first camera 1 and the second camera 2 are placed in substantially the same position. The first camera 1 and the second camera 2 photograph the golf ball

G from a back part. The third camera 3 is provided before the drop point Pe. The third camera 3 photographs the golf ball G from a front part. A distance between the first camera 1 and second camera 2 and the third camera 3 is represented as L. The position coordinates of the first camera 1 and the second camera 2 are (0, 0) and the position coordinates of the third camera 3 are (L, 0). The first camera 1, the second camera 2 and the third camera 3 are provided in such a manner that optical axes thereof are inclined upward in a horizontal direction. The inclination angle of the first camera 1 is greater than that of the second camera 2. The angle of view of the first camera 1 is surrounded by two-dotted chain lines L1a and L1b shown in Fig. 2. The angle of view of the second camera 2 is surrounded by two-dotted chain lines L2a and L2b. The angle of view of the first camera 1 partially overlaps with that of the second camera 2.

Description will be given to a method of calculating position coordinates (x, z) of the golf ball G by a triangulation method. When the golf ball G is launched, first of all, the golf ball G is photographed by the first camera 1 and the third camera 3. In this stage, the image of the golf ball G is not taken by the second camera 2. By the photographing, continuous image data are obtained. The image data obtained by the first camera 1 and the image data obtained by the third camera 3 make a pair. A black-and-white decision is carried out by horizontal scanning over frame data obtained by the first camera 1, and ball position in a vertical direction on the image are detected. Based on the result of the detection and a direction of an optical axis and an angle of view in the first camera 1, an angle of elevation θ_1 of the golf ball G in the position of the first camera 1 is calculated. Similarly, the black-and-white decision is carried out by the horizontal scanning over the frame data obtained by the third camera 3, and ball position in a vertical direction on the image are detected. Based on the result of the detection and a direction of an optical axis and an angle of view in the third camera 3, an angle of elevation

θ_3 of the golf ball G in the position of the third camera 3 is calculated.

The following equation (1) is obtained by a triangle formed by a foot Pf of a perpendicular drawn from the golf ball G, and the first camera 1 and the golf ball G to be apexes.

$$\tan \theta_1 = z/x \qquad (1)$$

On the other hand, the following equation (2) is obtained by a triangle formed by the foot Pf of the perpendicular drawn from the golf ball G, and the third camera 3 and the golf ball G to be apexes.

$$\tan \theta_3 = z/(L - x) \qquad (2)$$

The following equations (3) and (4) are obtained from the equations (1) and (2).

$$x = (L \cdot \tan \theta_3) / (\tan \theta_1 + \tan \theta_3) \qquad (3)$$

$$z = (L \cdot \tan \theta_1 \cdot \tan \theta_3) / (\tan \theta_1 + \tan \theta_3) \qquad (4)$$

The distance L between the first camera 1 and the third camera 3 and the angles of elevation θ_1 and θ_3 which are calculated are substituted for the equations (3) and (4), and the position coordinates (x, z) of the golf ball G are calculated. The position coordinates (x, z) are obtained as time series data with the flight of the golf ball G.

As described above, the angle of view of the first camera 1 partially overlaps with that of the second camera 2. For a certain period of the flight, therefore, the image of the golf ball is photographed by both the first camera 1 and the second camera 2. The first camera 1 and the second camera 2 are synchronized with each other. Therefore, the angle of view of the first camera 1 and that of the second camera 2 are related to each other based on data on images photographed at the same time. In other words, the correspondence of the coordinates in the angle of view of the first camera 1 to those in the angle of view of the second camera 2 is grasped by calculating means.

When the golf ball G further flies, it gets out of the angle of view of the first camera 1. Then, the golf ball G is photographed by the second camera 2 and the third camera 3. Based on the image data obtained by the second camera 2 and the

third camera 3, the position coordinates (x, z) of the golf ball G are calculated by the triangulation method. Since the angle of view of the first camera 1 is related to that of the second camera 2, continuous position coordinate data can be measured with high precision within a wide range of the trajectory T. As described above, the angles of view are related to each other based on the data on images photographed at the same time. Even if precision in the installation of the optical axis of the camera is insufficient, therefore, the position coordinates (x, z) are calculated with high precision.

In the method shown in Fig. 2, in the case in which the golf ball G flies without a substantial transverse shift from a target direction, measurement is carried out. If the flight is shifted from the target direction, a transverse direction (a perpendicular direction to the paper in Fig. 2) is set to be a Y axis. An angle of elevation of the golf ball G in the position of the first camera 1 is represented as θ_{11}, an angle of elevation of the golf ball G in the position of the third camera 3 is represented as θ_{31}, an angle in a transverse direction of the golf ball G in the position of the first camera 1 is represented as θ_{12}, and an angle in a transverse direction of the golf ball G in the position of the third camera 3 is represented as θ_{32}. θ_{11}, θ_{31}, θ_{12} and θ_{32} are obtained by an image processing based on the image data. Position coordinates (x, y, z) of the golf ball G are obtained by substituting θ_{11}, θ_{31}, θ_{12} and θ_{32} for the following equations (5), (6) and (7).

$$y = (L \cdot \tan\theta_{12} \cdot \tan\theta_{32}) / (\tan\theta_{12} + \tan\theta_{32}) \tag{5}$$

$$0 = ((\tan\theta_{11})^2 + (\tan\theta_{31})^2) \cdot x^2 + 2 \cdot (\tan\theta_{31})^2 \cdot L \cdot x + ((\tan\theta_{11})^2 - (\tan\theta_{31})^2) \cdot y^2 - (\tan\theta_{31})^2 \cdot L^2 \tag{6}$$

$$0 = (\tan\theta_{11})^2 \cdot (x^2 + y^2) - z^2 \tag{7}$$

Also in this case, the photographing is relayed by the first camera 1 and the second camera 2 which have mutual angles of view related to each other. Consequently, the measurement can be carried out within a wide range of the trajectory T.

At least three cameras for photographing the golf ball G from a back part may be provided to relay the photographing.

At least two cameras for photographing the golf ball G from a front part may be provided to relay the photographing.

Fig. 3 is a typical side view showing another measuring method using the apparatus of Fig. 1. In this example, the first camera 1 is provided behind the launch point Ps, the second camera 2 is provided between the launch point Ps and the drop point Pe, and the third camera 3 is provided before the drop point Pe. The first camera 1 and the second camera 2 photograph the golf ball G from a back part. The third camera 3 photographs the golf ball G from a front part. The angle of view of the first camera 1 is surrounded by two-dotted chain lines L1a and L1b. The angle of view of the second camera 2 is surrounded by two-dotted chain lines L2a and L2b. The angle of view of the first camera 1 partially overlaps with that of the second camera 2. The angle of view of the first camera 1 is related to that of the second camera 2.

Also in the measuring method, first of all, the golf ball G is photographed by the first camera 1 and the third camera 3. The photographing of the first camera 1 is relayed to the second camera 2. Then, the golf ball G is photographed by the second camera 2 and the third camera 3. Based on image data thus obtained, the coordinate position (x, z) or (x, y, z) of the golf ball G is calculated by the triangulation method.

In an example shown in Fig. 3, the golf ball G is photographed immediately before a drop by the second camera 2. The Z coordinate of the golf ball G which is obtained immediately before the drop is small. If the second camera 2 is placed in the same position as the first camera 1, the angle of elevation of the golf ball G obtained immediately before the drop by the second camera 2 is small. On the other hand, if the second camera 2 is positioned between the launch point Ps and the drop point Pe as shown in Fig. 3, the angle of elevation of the golf ball G obtained immediately before the drop by the second camera 2 is comparatively great. The great angle of elevation contributes to an enhancement in precision in the measurement. The reason will be described below.

It is assumed that the position coordinates of the golf ball G obtained immediately before the drop are (200, 3), the position coordinates of the second camera 2 are (0, 0) and the position coordinates of the third camera 3 are (300, 0). In other words, it is assumed that the second camera 2 is provided behind the launch point Ps. In this case, an angle of elevation θ_2 of the golf ball G from the second camera 2 is calculated as 0.86 degree by the following equation.

$\theta_2 = \tan^{-1} (3/200)$

On the other hand, an angle of elevation θ_3 of the golf ball G from the third camera 3 is calculated as 1.72 degrees from the following equation.

$\theta_3 = \tan^{-1} (3/(300 - 200))$

If the angle of elevation θ_2 obtained based on the image data of the second camera 2 is 0.91 degree (that is, a value obtained with a shift of 0.05 degree from the original value of 0.86 degree), the position coordinates (x, y) of the golf ball G are calculated as (196.2, 3.1) by the following equation.

x = (300 · tan(1.72)) / (tan(0.91) + tan(1.72))

z = (300 · tan(0.91) · tan(1.72)) /
    (tan(0.91) + tan(1.72))

"196.2" to be the x coordinate thus calculated is smaller than "200" to be an actual x coordinate by 3.8.

In the case in which the position coordinates of the second camera 2 are (150, 0), in other words, the second camera 2 is close to the drop point Pe, the angle of elevation θ_2 is calculated as 3.43 degrees by the following equation.

$\theta_2 = \tan^{-1}(3 / (200 - 150))$

If the angle of elevation θ_2 obtained based on the image data of the second camera 2 is 3.48 degrees (that is, a value obtained with a shift of 0.05 degree from the original value of 3.43 degrees), the position coordinates (x, z) of the golf ball G are calculated as (199.6, 3.0) by the following equation.

x = (150 · tan(1.72)) / (tan(3.48) + tan(1.72))

z = (150 · tan(3.48) · tan(1.72)) /
    (tan(3.48) + tan(1.72))

"199.6" to be the x coordinate thus calculated is very close to "200" to be an actual x coordinate. Thus, the second camera 2 is provided in such a position that the golf ball G can be photographed immediately before the drop at a great angle of elevation. Consequently, the precision in the measurement can be enhanced.

In respect of the precision in the measurement, it is preferable that the second camera 2 should be provided in such a position that the inclination angle of the optical axis thereof is 3 to 40 degrees. The inclination angle is more preferably 5 to 40 degrees and particularly preferably 7 to 40 degrees. From the viewpoint of the precision in the measurement, it is preferable that the second camera 2 should be provided close to the third camera 3 from the middle point of the first camera 1 and the third camera 3.

It is preferable that the distances of the first camera 1, the second camera 2 and the third camera 3 from the ground should be 3 m or less. If the distance from the ground is more than 3 m, it is hard to measure the golf ball G immediately after the launch and immediately before the drop. From this viewpoint, it is more preferable that the distance from the ground should be 2 m or less. An ideal distance from the ground is zero.

At least three cameras for photographing the golf ball G from a back part may be provided to relay the photographing. At least two cameras for photographing the golf ball G from a front part may be provided to relay the photographing.

Fig. 4 is a typical side view showing a state in which the trajectory of a golf ball is measured by a ball trajectory measuring apparatus according to another embodiment of the present invention. This apparatus comprises a first camera 4, a second camera 5 and a third camera 6 which are the same as those of the apparatus in Fig. 1. This apparatus comprises the same components as the control portion 4 and the calculating portion 5 of the apparatus in Fig. 1, which are not shown.

The first camera 4 is provided before a drop point Pe, the second camera 5 is provided between a launch point Ps and

the drop point Pe, and the third camera 6 is provided behind the launch point Ps. The first camera 4 and the second camera 5 photograph a golf ball G from the front part. The third camera 6 photographs the golf ball G from the back part. The angle of view of the first camera 4 is surrounded by two-dotted chain lines L1a and L1b. The angle of view of the second camera 5 is surrounded by two-dotted chain lines L2a and L2b. The angle of view of the first camera 4 partially overlaps with that of the second camera 5. The angle of view of the first camera 4 is related to that of the second camera 5.

In the measuring method, first of all, the golf ball G is photographed by the second camera 5 and the third camera 6. The photographing of the second camera 5 is relayed to the first camera 4. Then, the golf ball G is photographed by the first camera 4 and the third camera 6. Based on image data thus obtained, the coordinate position (x, z) or (x, y, z) of the golf ball G is calculated by the triangulation method.

In an example shown in Fig. 4, the golf ball G is photographed immediately after a launch by the second camera 5. The Z coordinate of the golf ball G which is obtained immediately after the launch is small. If the second camera 5 is placed in the same position as the first camera 4, the angle of elevation of the golf ball G obtained immediately after the launch by the second camera 5 is small. On the other hand, if the second camera 5 is positioned between the launch point Ps and the drop point Pe as shown in Fig. 4, the angle of elevation of the golf ball G obtained immediately after the launch by the second camera 5 is comparatively great. The great angle of elevation contributes to an enhancement in precision in the measurement.

In respect of the precision in the measurement, it is preferable that the second camera 5 should be provided in such a position that the inclination angle of the optical axis thereof in a horizontal direction is 3 to 40 degrees. The inclination angle is more preferably 5 to 40 degrees and particularly preferably 7 to 40 degrees. From the viewpoint

of the precision in the measurement, it is preferable that the second camera 5 should be provided close to the third camera 6 from the middle point of the first camera 4 and the third camera 6.

At least two cameras for photographing the golf ball G from a back part may be provided to relay the photographing. At least three cameras for photographing the golf ball G from a front part may be provided to relay the photographing.

While the apparatus according to the present invention has been described above by taking, as an example, the case in which the trajectory of the golf ball G is measured, it is also suitable for measuring the trajectory of another ball.

The above description is only illustrative and can be variously changed without departing from the scope of the present invention.